MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ERT3016 – ROBOTICS

(RE)

8 MARCH 2017
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages including cover page with 5 Questions only. DH-parameter procedures are included in Appendix

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

a) Explain why industrial robots are important. And, list two application areas of industrial robots.

[4+2 marks]

b) Define the following technical terms:
   i. Joint
   ii. Configuration
   iii. Workspace

[2+2+2 marks]

c) Compare the advantages and disadvantages of electrical, hydraulic and pneumatic drive systems.

[8 marks]

Question 2

Given that $F = \{f^1, f^2, f^3\}$ and $M = \{m^1, m^2, m^3\}$ are two initially coincident fixed and mobile coordinate frames respectively. Suppose we perform a screw transformation along axis f^2 by a distance of $\lambda = 5$ and rotating by an angle of π.

a) Draw the coordinate frames showing the screw transformation.

[5 marks]

b) Compute the screw pitch.

[2 marks]

c) Determine the transformation matrix T.

[4 marks]

d) Find coordinate $[p]^F$ if the coordinate p with respect to the mobile frame is $[p]^M = [3, 5, 7]^T$

[3 marks]

e) In your own words, describe how to reverse the screw transformation.

[2 marks]

f) Determine T^{-1}.

[4 marks]

Continued .....

Question 3

Consider a 4-DOF SCARA robot shown in the Figure 1. $J1, J2$ and $J4$ are revolute joints. Meanwhile, $J3$ is a prismatic joint. Given that $L_{11} = 200mm$, $L_{12} = 100mm$, $L_2 = 300mm$, $L_4 = 100mm$, and $d_3 = 150mm$.

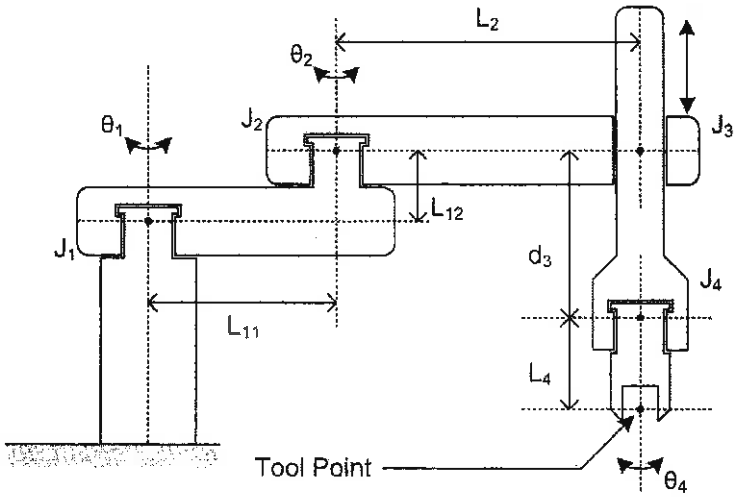

Figure 1

a) Draw the link-coordinate diagram for the robot.

[7 marks]

b) Fill in the kinematic parameters in the following table.

Axis	θ	d	a	α	Home
1					0
2					0
3					-150mm
4					0

[4 marks]

c) Determine the arm matrix $T_{base}^{tool}(q)$ at home position.

[9 marks]

Continued .....

Question 4

Consider a three-axis robot with the kinematics parameters shown in the following table.

Axis	θ	d	a	α
1	q_1	0	0	0
2	$-\frac{\pi}{2}$	q_2	0	$\frac{\pi}{2}$
3	0	q_3	0	$-\frac{\pi}{2}$

a) Determine the general arm equation, $T_0^3(q)$.

[13 marks]

b) Given that

$$T_0^3(q) = \begin{bmatrix} 0.5 & 0.866 & 0 & -173.2 \\ -0.866 & 0.5 & 0 & -100 \\ 0 & 0 & 1 & 150 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Solve the inverse kinematics equations to find the joint variables q_n where $n = 1, 2, 3$.

[7 marks]

Continued .....

Question 5

a) Consider the top view of a robotic workstation, with Part A and Part B, as shown in Figure 2. Suppose the centroid of Part A has coordinate $[2, 5, 7]^T$ and the centroid of Part B has coordinate $[9, 10, 2]^T$.

i. Find the arm matrix value T_{base}^{pick} needed to pick up Part A above by grasping it in the middle of the long sides.

[4 marks]

ii. Find the arm matrix value T_{base}^{pick} needed to pick up Part B above by grasping it in the middle of the long sides.

[4 marks]

iii. Find the arm matrix value T_{base}^{place} needed to place Part B on top of Part A, aligning the centroid and the major axis.

[4 marks]

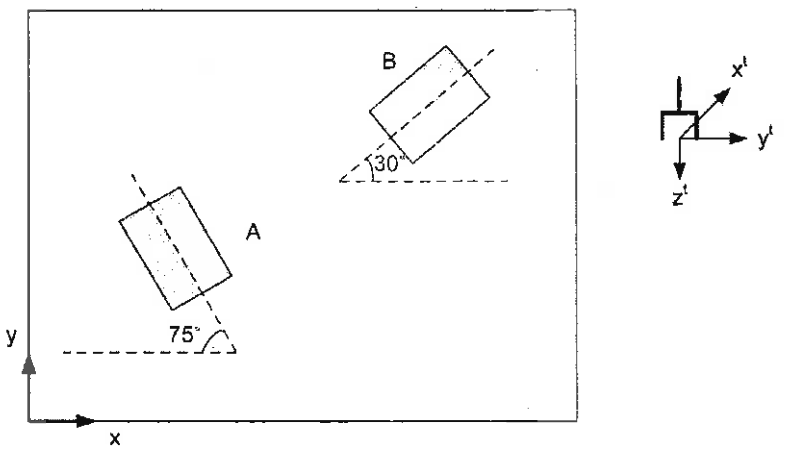

Figure 2

b) The first joint of a 4-axis robot is to go from initial angle of 35° to an end position of 135° in 5 seconds. The trajectory is done using a third-order polynomial. Calculate the joint angle and velocity at time 3 seconds. Assume the robot starts at rest and all joints stop at end point.

[8 marks]

Continued .....

Appendix

Procedure to DH-Parameter

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set $k=1$.
3. Align z^k with the axis of joint $k+1$.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set $k=1$.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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